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RESEARCH ARTICLE

Environmental Health Risk Analysis of Heavy Metals Copper (Cu) and Arsenic (As) in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province

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ABSTRACT

Mining activities can also cause water pollution due to the use of chemicals, which include hazardous and toxic materials, and exposure to chemicals from mines that pollute water sources. Analyze the risks due to exposure to copper (Cu) and arsenic (As) in communities living and residing and doing activities in the gold mining area of PT. Citra Palu Mineral, Central Sulawesi Province. Observational research using the Environmental Health Risk Assessment (EHRA) method or Environmental Health Risk Analysis (ARKL) to assess or estimate the magnitude of human health risks caused by exposure to environmental hazards. The highest concentration of heavy metal copper (Cu) was 0.029 and the lowest was 0.0088. The concentration of heavy metal arsenic (As) at points 1, 2, and 3 showed a concentration value of 0.0081. Exposure to heavy metal copper through the dermal exposure pathway is stated to be at risk specifically for adults because the RQ value is > 1. Heavy metal copper (Cu) and arsenic (As) through ingestion and dermal exposure are stated to be at risk because the RQ value is > 1. Conclusion. The average risk level (risk quotient) of exposure to heavy metals copper (Cu) and arsenic (As) in wastewater at PT. Citra Palu Mineral, Central Sulawesi Province, RQ > 1 so that it is stated to be at health risk.

1. INTRODUCTION

Mining activities in Indonesia have been going on for a long time, carried out by large and small-scale mining business actors, community mining, and illegal mining (PETI) (1). One of the very clear impacts of mining activities is environmental damage such as residual material from the production process called tailings. Tailing waste, which is dregs from the remaining processing of mining materials, has quite a large potential to increase pollutants in the environment (2). In gold and silver mining operations, there are often several other elements that are present and dissolved in mining exploitation, these elements are copper (Cu), tin (Sn), zinc (Zn), nickel (Ni), iron (Fe), and mercury (Hg) (3).

Based on data from the World Health Organization (4), it is known that the percentage of deaths due to unsafe water and sanitation, as well as lack of adequate hygiene, is the third highest in succession in Chad (101%), Somalia (86.6%), and the Central African Republic (82.1%). Although the African continent ranks first in the problem of deaths caused by unsafe water sources, Indonesia is included in the top 60 countries with deaths caused by unsafe water sources (7.1%). Meanwhile, in Southeast Asia, Indonesia is in sixth place after Nepal (19.8%), India (18.6%), Myanmar (12.6%), Bangladesh (11.9%), and Timor-Leste (9.9%).

Mining not only generates financial profits but can also have a negative impact on the environment. Gold mining produces waste from the separation of gold and the cleaning of minerals, which consists

of organic and inorganic minerals. Gold mining involves washing, tailings disposal, and stripping of the topsoil, known as topsoil, which can affect the physical, chemical, and biological characteristics of soil and water. Waste containing metals is one of the water pollutants.
Gold processing produces wastewater or waste that is directly discharged into the waste disposal tank because no layer prevents waste from seeping and polluting the soil and surrounding environment. There is no good management causing waste to seep and seep, polluting the Poboya river water (5).

It is undeniable that the impact of mining activities can have a positive effect on an area and mining companies. However, gold mining activities can also cause low environmental quality (6). To control environmental damage caused by mining activities, good cooperation is needed from all stakeholders (companies, government, and the community) to properly control the implementation of mining so that it is safe and comfortable so that the environment is well maintained (6,7).

One source of pollution from the chemical aspect is the heavy metal Arsenic (As). Arsenic has been known as a toxic source since ancient times, but its use is still carried out today. The International Agency for Research on Cancer (8) stated that Arsenic is in the first class as a carcinogen without a minimum threshold value, and in small amounts, It can cause negative effects on human health.

Arsenic is one of the most toxic elements found naturally in soil, water, and air (9). It is generally bound as a sulfide salt. Arsenic seeds are often associated with tin, nickel, cobalt, silver, lead, and gold. Therefore, arsenic is also produced as a by-product of mining activities, including gold mining (10).

High levels of arsenic contamination are of concern because arsenic can cause several human health effects. Several epidemiological studies have reported a strong association between arsenic exposure and increased risk of carcinogenic and systemic health effects (11).

Nearly every organ system is affected by arsenic exposure. These include the cardiovascular, dermatological, nervous, hepatobiliary, renal, gastrointestinal, and respiratory systems. In addition, studies have shown significantly higher standardized mortality rates from bladder, kidney, skin, and liver cancers in many arsenic-polluted sites. The chemical form of arsenic correlates with the degree of health damage, and timing and dose also play a role. There is strong evidence that arsenic can cause tumors in humans, but the mechanisms by which it causes tumors in humans are still not fully understood (11).

Research from (12) analyzed wastewater from illegal gold mining in Bakan Village. States that arsenic levels at 4 points in the Bakan Village River have not exceeded the standard quality limit. According to (13) in (14) low levels of heavy metals in water do not guarantee that heavy metals contained in pollutants do not have a negative impact on waters.

In addition to the heavy metal arsenic (As), there is another heavy metal, namely copper. Copper is an important heavy metal because it is needed by humans, other mammals, and fish for metabolism, the formation of hemoglobin, hemocyanin, and pigments in the process of transporting oxygen (15). Good copper consumption for humans is 2.5 mg/kg body weight/day for adults and 0.05 mg/kg body weight/day for children and infants (16). However, in amounts exceeding this limit can be toxic. If fish or aquatic organisms containing copper are eaten by humans, copper can enter the body and affect health.

This study is a study on the analysis of environmental health risks due to exposure to environmental risk agents, namely heavy metals copper (Cu) and arsenic (As). There are several reasons for choosing the topic in this study, namely that so far there have been few studies that have taken the risk agents of heavy metals copper (Cu) and arsenic (As), previous studies have been more dominant on risk agents mercury (Hg), cadmium (Cd), chromium (Cr) in the concept of risk analysis in the environment.

Environmental Health Risk Analysis (EAHR) of Copper (Cu) and Arsenic (As) exposure through wastewater in the Tanjung Pering Village community has never been done before. Environmental health risk analysis is important to estimate the health risks of exposure to heavy metals Copper (Cu) and Arsenic (As). The Environmental Health Risk Analysis (EAHR) method is carried out to identify what hazards and losses will occur, understand the relationship between the dose of risk agents and the body's response, measure the amount of exposure to risk agents, and determine the level of risk and health effects on the population. Then the EAHR method is carried out to determine whether or not control is needed due to Arsenic exposure in the community who live and reside and are active in the gold mining area of PT. Citra Palu Mineral, Central Sulawesi Province, now and in the future.

2. MATERIALS AND METHODS

2.1. Type and design of research

This type of research is an observational study using the Environmental Health Risk Assessment (EHRA) method or Environmental Health Risk Analysis (ARKL) to assess or estimate the magnitude of human health risks caused by exposure to environmental hazards (17)

2.2. Population and sample

The study was conducted in the Gold Mining area of PT. Citra Palu Mineral, Central Sulawesi Province, namely the community within the scope of the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province using the purposive sampling technique. The number of environmental samples was 3 points adjacent to the mining location for the examination of heavy metals arsenic (As) and copper (Cu) and 100 human samples with adult and child respondent categories.

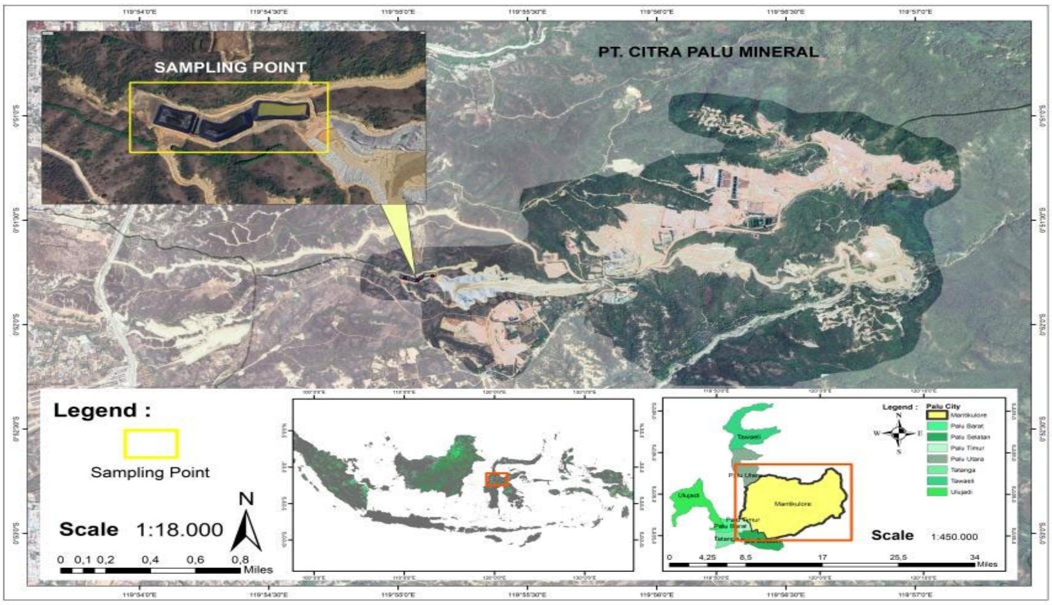

Figure 1: Sampling point map2.3. Research instruments

2.3.1. Sampling techniques

Sampling for wastewater quality testing a) prepare the sampling tool according to the drainage channel; b) rinse the tool with the sample to be taken, 3 (three) times; c) take samples according to the analysis designation and mix in a temporary container, then homogenize; d) put it in a container suitable for the analysis designation; e) immediately carry out testing for temperature, turbidity and electrical conductivity, pH and dissolved oxygen parameters that can change quickly and cannot be preserved; f) the results of field parameter testing are recorded in a special notebook; g) sampling for laboratory testing parameters is preserved.

2.3.2. Risk analysis and environmental health risk

$$\boldsymbol{I} = \frac{\boldsymbol{C\ x\ R\ x\ t_E\ x\ f_E} \times D_t}{\boldsymbol{W_b\ x\ t_{avg}}} \quad (1)$$

Description:
I = Intake (mg/kg/Day)
C = Concentration of risk agent, mg/m3 (air), mg/L (drinking water), mg/kg (food)
R = Intake or consumption rate, m3/h (inhalation), L/day (drinking water), g/day (food)
t_E = exposure time
f_E = frequency of exposure
D_t = Exposure duration, years (real-time or default)
Wb= body weight (kg)

t_{avg} = Average time period (30 x 365 days/year for realtime, 70 years x 365 days/year for lifetime)

$$RQ = \frac{I}{RfD} \qquad (2)$$

Description:
RQ = Risk characterization
RfD = Response concentration analysis
I = Intake (exposure)

Risk characteristics for carcinogenic effects are calculated by multiplying intake by SF (slope factor). Reference values of risk agents with carcinogenic effects are obtained from the website www.epa.gov/iris

3. RESULT AND DISCUSSION

3.1. Research location

Gold mining carried out by PT. Citra Palu Minerals located in Poboya Village, Mantikulore District, Palu City, Central Sulawesi Province. Geographically located in the easternmost part of Palu City with the northern boundary being Mantikulore District and the Grand Forest Park, the South bordering the South Palu District, the East bordering the Grand Forest Park and Parigi Regency and the West bordering the East Palu District and Palu City.

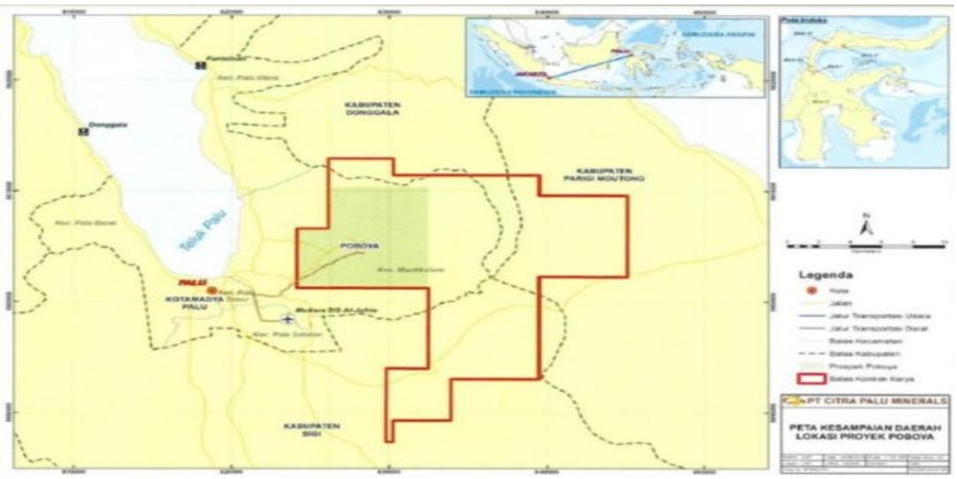

Figure 2: Overview of research location4. Risk assessment

4.1. Hazard identification

Hazard identification is used to determine the concentration of specific risk agents that have the potential to cause health problems if the body is exposed to either a short or long period (18,19). The risk agents analyzed in this study were copper and arsenic concentrations.

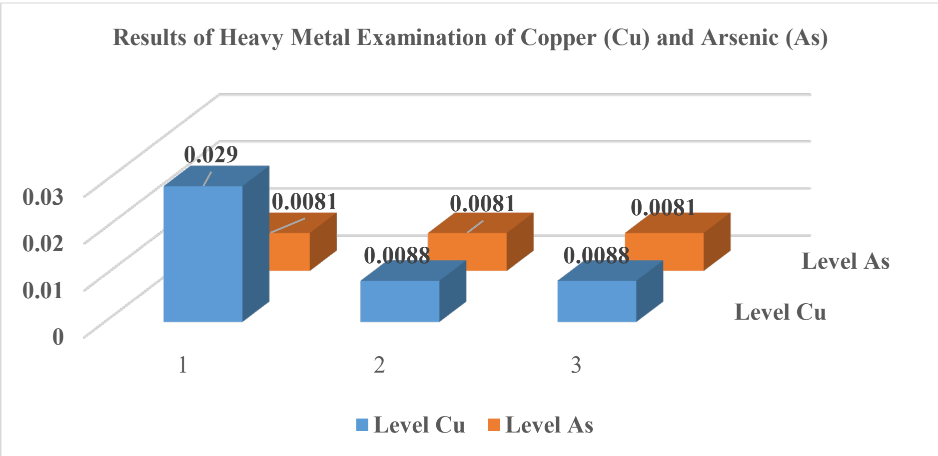

Figure 3: Graph of water sample examination results for heavy metal parameters Copper (Cu) and Arsenic (As)

Based on Figure 3, shows that the concentration of heavy metal copper (Cu) at point 1 is 0.029 while at points 2 and 3 it shows a concentration of 0.0088. The concentration of heavy metal arsenic (As) at points 1, 2, and 3 shows a concentration value of 0.008.

4.2. Exposure analysis

Exposure analysis aims to identify and calculate the number of exposed populations and the duration of exposure to agents (20). The amount of exposure to water pollution is measured by calculating the amount of intake that enters the body (21). Determination of exposure analysis (exposure assessment) is carried out by entering the values of anthropometric characteristics and human activities into a formula (Microsoft Excel) (22):

Table 1: Respondent characteristics based on body weight and community activity patterns around the tamangapa landfill area

Indicator	Min	Max	Mean	information
Weight	10	75		Kg
Intake Rate (IR)	1	2	1.5000	L/day
Exposure Duration (ED)	12	67	38.3947	year
Average Time (AT)	2190	10950	6570	Day
Exposure Frequency (EF)	356	356	356	day/year

Table 1, shows that the respondents' body weight ranged from 12 kg to 75 kg and an average of 39.6 kg. The respondents' ingestion rate for children was 1 L/Day and for adults 2 L/Day. The respondents' exposure duration ranged from 12 to 67 years, averaging 38 years. The respondents' exposure frequency ranged from 356 days/year and an average of 356 days/year.

4.3. Copper and arsenic exposure intake

The intake value is the exposure value by analyzing respondents' characteristics to determine each risk agent measured from clean water in the PT. Gold Mining Area. Citra Palu Mineral, Central Sulawesi Province. The results of the calculation of intake that enters the body in the real-time projection (Dt), minimum, maximum, and mean values are presented in the following table:

Table 3: Min, max, and mean ADD values of respondents for ingestion path copper exposure in the gold mining area of PT. Citra Palu mineral, central Sulawesi province

Intake (ml/L/day)	Min		Max		Mean		information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	0.000172	0.2464	0.000687	1.7062	0.000353	0.505057	MS	TMS
Lifetime								
5	0.000858	1.2318	0.003433	8.5310	0.001763	2.525287	MS	TMS
10	0.001717	2.4636	0.006866	17.0620	0.003526	5.050573	TMS	TMS
15	0.002575	3.6954	0.0103	25.5930	0.005289	7.575860	TMS	TMS
20	0.003433	4.9272	0.013733	34.1240	0.007052	10.101146	TMS	TMS
25	0.004292	6.1590	0.017166	42.6550	0.008815	12.626433	TMS	TMS
30	0.00515	7.3908	0.020599	51.1860	0.010578	15.151719	TMS	TMS

Description: MS (Eligible), TMS (Not Eligible)
*Note: RfD 0.004 ml/L/day

Source: Primary Data, 2024Based on Table 3, the real-time ADD intake value of non-carcinogenic copper exposure through the ingestion route (oral) of 100 respondents, the results show that the mean value for adults is 0.505057, which is higher than for children, which is 0.000353. Meanwhile, the lifetime ADD intake of non-carcinogenic Ammonia exposure projection for years 5-30 has a mean value for children, which is 0.001763 - 0.010578 ml/L/day, which is lower than for adults, which is 2.525287 - 15.151719 ml/L/day.

Table 4: Min, max, and mean ADD values of respondents for ingestion path arsenic exposure in the gold mining area of PT. Citra Palu mineral, central Sulawesi province

Intake (ml/L/day)	Min		Max		Mean		information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	0.000158	0.001416	0.000632	0.002647	0.000325	0.002017	MS	TMS
Lifetime								
5	0.00079	0.007079	0.00316	0.013233	0.001623	0.010086	TMS	TMS
10	0.00158	0.014157	0.00632	0.026466	0.003245	0.020172	TMS	TMS
15	0.00237	0.021236	0.00948	0.039669	0.004868	0.030259	TMS	TMS
20	0.00316	0.028315	0.01264	0.52932	0.006491	0.040345	TMS	TMS
25	0.00395	0.035393	0.015801	0.066165	0.008114	0.050431	TMS	TMS
30	0.00474	0.042472	0.018961	0.079398	0.009736	0.060517	TMS	TMS

Description: MS (Eligible), TMS (Not Eligible)
*Note: RfD 0.0003 ml/L/day

Source: Primary Data, 2024Based on Table 4, the real-time ADD intake value of non-carcinogenic Arsenic exposure through the ingestion route (oral) of 100 respondents shows that the mean value for adults is 0.002017 higher than for children, which is 0.000325. Meanwhile, the lifetime ADD intake of non-carcinogenic Ammonia exposure projection for years 5-30, the mean value for children is 0.001623 - 0.009736 ml / L / day, which is lower than for adults, which is 0.010086 - 0.060517 ml / L / day. In real-time intake and projections for the 5th year, the mean ADD for non-carcinogenic children still meets the requirements, because it is lower than the RfD value of 0.004 ml / L / day.

Table 5: Min, max, and mean ADD values of respondents for dermal copper exposure in the gold mining area of PT. Citra Palu mineral, central Sulawesi province

Intake (ml/L/day)	Min		Max		Mean		information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	0.000001	0.498127	0.000007	0.931208	0.000004	0.709768	MS	TMS
Lifetime								
5	0.000009	2.490635	0.00039	4.656041	0.0002	3.548839	MS	TMS
10	0.000195	4.981269	0.00078	9.312082	0.000401	7.097678	MS	TMS
15	0.000293	7.471904	0.00117	13.96812	0.000601	10.64652	MS	TMS
20	0.00039	9.962538	0.001561	18.62416	0.000801	14.19536	MS	TMS
25	0.000488	12.45317	0.001951	23.28021	0.001002	17.7442	MS	TMS
30	0.000585	14.94381	0.002341	27.93625	0.001202	21.29303	MS	TMS

Description: MS (Eligible), TMS (Not Eligible)
*Note: RfD 0.004 ml/L/day

Source: Primary Data, 2024Based on Table 5, of real-time ADD intake values of non-carcinogenic Copper exposure through the dermal (skin) route of 100 respondents, the results showed that the mean value for adults was 0.709768, higher than for children, which was 0.000004. While the lifetime ADD intake of non-carcinogenic Nitrate exposure projections for years 5-30, the mean value for children was 0.0002 - 0.001202 ml/L/day, lower than adults, which was 3.548839 - 21.29303 ml/L/day. In real-time intake, the mean ADD for non-carcinogenic children still meets the requirements, because it is lower than the RfD value of 0.004 ml/L/day

Table 6: Min, max, and mean ADD values of respondents for dermal route arsenic exposure in the gold mining area of PT. Citra Palu Mineral, Central Sulawesi province

Intake (ml/L/day)	Min		Max		Mean		information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	0.0000019	0.498127	0.0000078	0.931208	0.000004	0.709768	MS	TMS
Lifetime								
5	0.0000097	2.490635	0.00039	4.656041	0.0002	3.548839	MS	TMS
10	0.000195	4.981269	0.00078	9.312082	0.000401	7.097678	TMS	TMS
15	0.000293	7.471904	0.00117	13.96812	0.000601	10.64652	TMS	TMS
20	0.00039	9.962538	0.001561	18.62416	0.000801	14.19536	TMS	TMS
25	0.000488	12.45331	0.001961	23.28021	0.001002	17.7442	TMS	TMS
30	0.000585	14.94381	0.002341	27.93625	0.001202	21.29330	TMS	TMS

Description: MS (Eligible), TMS (Not Eligible)
*Note: RfD 0.0003 ml/L/day

Source: Primary Data, 2024Based on Table 6, the real-time ADD intake value of non-carcinogenic Arsenic exposure through the dermal (skin) route of 100 respondents shows that the mean value for adults is 0.709768, higher than for children, which is 0.000004. Meanwhile, the lifetime ADD intake of non-carcinogenic Nitrate exposure projections for years 5-30, the mean value for children is 0.0002 - 0.001202 ml/L/day, lower than adults, which is 3.548839 - 21.29330 ml/L/day. In real-time intake, the mean ADD for non-carcinogenic children still meets the requirements, because it is lower than the RfD value of 0.0003 ml/L/day.

4.4. Copper and arsenic exposure intake

Table 7: Respondents' Risk Quotient (RQ) values for copper and arsenic exposure in the gold mining area of PT. Citra Palu mineral, central Sulawesi province

Hazards and Exposure Routes	Exposure		Risk Quotient (RQ)	
	Children	Adults	Children	Adults
Copper Ingestion (Cu)	0.547891	0.088148	No Risk	No Risk
Copper Dermal (Cu)	2365.893	0.133557	At Risk	No Risk
Arsenic Ingestion (As)	6.72412	1.081811	At Risk	At Risk
Arsenic Dermal (As)	177.442	0.010017	At Risk	At Risk

Source: Primary Data, 2024

*Note: Risky if RQ > 1, not risky if RQ < 1

Based on table 7, shows that exposure to the heavy metal copper through the dermal exposure pathway is stated to be a specific risk for adults because the RQ value is > 1. Meanwhile, the heavy metals copper (Cu) and arsenic (As) through ingestion and dermal exposure, it is stated to be a risk because the RQ value is > 1.

4.5. Target hazard quotient (THQ)

Copper and Arsenic can enter the human body through the ingestion and dermal routes. Copper and Arsenic have implications for health risks. The risk level for non-carcinogenic effects is expressed in the Target Hazard Quotient (THQ) notation. The risk needs to be controlled if THQ>1 and if THQ <1 then the risk does not need to be controlled but all conditions must be maintained so that the THQ value does not exceed 1. Based on the calculation results of Copper and Arsenic intake that enters the body in real-time projections (Dt). The minimum, maximum, and mean values of the non-carcinogenic risk level are presented in the following table;

Table 8: Min, max, and mean THQ values of copper ingestion path in the gold mining area of PT. Citra Palu Mineral, Central Sulawesi Province

THQ (ml/L/day)	Min		Max		Mean		information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	20.5825	4610.479104	82.32998	8618.9202	20.5825	6569.34955	At Risk	At Risk
Lifetime								
5	102.91248	23052.39552	411.64992	43094.601	211.38223	32846.74776	At Risk	At Risk
10	205.82496	46104.79104	823.29984	86189.202	422.76447	65693.49552	At Risk	At Risk
15	308.73744	69157.18656	1234.9498	129283.803	634.1467	98540.24329	At Risk	At Risk
20	411.64992	92209.58208	1646.5997	172378.404	845.52894	13186.991	At Risk	At Risk
25	514.5624	115261.9776	2058.2496	215473.005	1056.9112	164233.7388	At Risk	At Risk
30	617.47488	138314.3731	2469.8995	258567.606	1268.2934	197080.4866	At Risk	At Risk

Description: MS (Eligible), TMS (Not Eligible)

*Note: Risky if THQ > 1, no risk if THQ < 1

Source: Primary data 2024

Based on Table 8, it can be seen that the target value of the non-carcinogenic real-time hazard quotient (THQ) of copper for 100 respondents (children and adults) is the mean value for adults of 6569.34955, which is higher than for children of 20.5825, which means that on average the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems in children and adults because the THQ value is >1. While the THQ lifetime projection for the 5th - 30th year for children is around 211.38223 - 1268.2934 and for adults around 32846.74776 - 197080.4866, it can be concluded that in terms of lifetime 5 - 30 years, the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems

Table 9: Min, max, and mean THQ values of arsenic ingestion path in the gold mining area of PT. Citra Palu mineral, central Sulawesi province

THQ (ml/L/day)	Min		Max		Mean		information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	2526.034	565831.526	10104.13	1057776.57	5188.473	806238.3542	At Risk	At Risk
Lifetime								
5	12630.17	2829157.63	50520.67	5288882.85	25942.37	4031191.771	At Risk	At Risk
10	25260.34	6558315.26	101041.3	10577765.7	51884.73	8062383.542	At Risk	At Risk
15	37890.5	8487472.9	151562	15866648.55	77827.1	12093575.31	At Risk	At Risk
20	50520.67	11316630.5	202082.7	21155531.4	103769.5	16124767.08	At Risk	At Risk
25	63150.84	14145788.2	252603.4	26444414.25	129711.8	20155958.85	At Risk	At Risk
30	75781.01	16974945.8	303124	31733297.1	25942.37	24187150.3	At Risk	At Risk

Description: MS (Eligible), TMS (Not Eligible)
*Note: Risky if THQ > 1, no risk if THQ < 1
Source: Primary data 2024

Based on Table 9, it can be seen that the target value of the real-time non-carcinogenic hazard quotient (THQ) for arsenic of 100 respondents (children and adults) is the mean value for adults of 4031191.771, which is higher than for children of 5188.473, which means that on average the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems in children and adults because the THQ value is >1. While the THQ lifetime projection for the 5th - 30th year for children is around 25942.37-25942.37 and adults around 4031191.771- 24187150.3, it can be concluded that in terms of lifetime 5 - 30 years, the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems.

Table 10: Min, max, and mean THQ values of copper dermal line in gold mining area of PT. Citra Palu mineral, central Sulawesi province

THQ (Ml/L/Day)	Min		Max		Mean		Information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	0.233892	14931.67	0.935568	27913.55	0.480414	21275.73	No Risk	At Risk
Lifetime								
5	1.16946	74658.33	4.67784	139567.7	2.402071	10378.7	At Risk	At Risk
10	2.33892	149316.7	9.35568	279135.5	4.804142	212757.3	At Risk	At Risk
15	3.50838	223975	14.03352	418703.2	7.206213	319136	At Risk	At Risk
20	4.67784	298633.3	18.71136	558271	9.608283	425514.7	At Risk	At Risk
25	5.8473	373291.6	23.3892	697838.7	12.01035	531893.4	At Risk	At Risk
30	7.01676	447950	28.06704	837406.5	14.41243	638272	At Risk	At Risk

Description: MS (Eligible), TMS (Not Eligible)
*Note: Risky if THQ > 1, no risk if THQ < 1
Source: Primary data 2024

Based on Table 10, it can be seen that the target value of the non-carcinogenic real-time hazard quotient (TRQ) for copper of 100 respondents (children and adults) is the mean value for adults of 21275.73, which is higher than for children, which is 0.480414, which means that on average, the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems in children and adults because the THQ value is >1. While the THQ lifetime projection for the 5th - 30th year for children is around 2.402071 - 14.41243 and adults around 10378.7 - 638272, it can be concluded that in terms of lifetime 5 - 30 years, the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems.

Table 11: Min, max, and mean THQ values of dermal path arsenic in the gold mining area of PT. Citra Palu mineral, central Sulawesi province

THQ (Ml/L/Day)	Min		Max		Mean		Information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
Realtime	14931.67	73847500.8	2105028	27913.55	864230.94	21275.73	At Risk	At Risk
Lifetime								
5	74658.33	369237504	10525140	139567.7	4321154.7	106378.7	At Risk	At Risk
10	149316.7	738475008	21050280	279135.5	8642309.4	212757.3	At Risk	At Risk
15	223975	1107712512	31575420	48703.2	12963464.1	319136	At Risk	At Risk
20	298633.3	1476950016	42100560	558271	17284618.8	425514.7	At Risk	At Risk
25	373291.6	1846187520	52625700	697838.7	21605773.5	531893.4	At Risk	At Risk

THQ (Ml/L/Day)	Min		Max		Mean		Information	
	Children	Adults	Children	Adults	Children	Adults	Children	Adults
30	447950	2215425024	63150840	837406.5	25926928.2	638272	At Risk	At Risk

Description: MS (Eligible), TMS (Not Eligible)
*Note: Risky if THQ > 1, no risk if THQ < 1
Source: Primary data 2024

Based on Table 11, it can be seen that the target value of the real-time non-carcinogenic hazard quotient (THQ) for arsenic of 100 respondents (children and adults) is the mean value for adults 21275.73, which is higher than for children 864230.94, which means that on average, the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems in children and adults because the THQ value is >1. Meanwhile, the THQ lifetime projection for the 5th - 30th year for children is around 4321154.7 - 25926928.2 and for adults around 106378.7 - 638272, so it can be concluded that in terms of lifetime 5 - 30 years, the community in the Gold Mining Area of PT. Citra Palu Mineral, Central Sulawesi Province is at risk of experiencing health problems.

4.6. Risk management

In the calculation of Environmental Health Risk Analysis, the risk management carried out is by determining the safe limit that can protect the population, namely by reducing the duration of exposure, safe exposure frequency, and safe exposure time. Risk management is carried out with the aim that individuals or populations at risk of exposure to risk agents can remain safe from health problems due to risk agents by manipulating existing components to obtain a THQ value <1.

5. DISCUSSION

5.1. Environmental health risk analysis (EAHR)

Environmental Health risk analysis is carried out through four steps, namely, hazard identification, dose-response analysis, exposure analysis, and risk characteristics. After conducting an environmental Health risk analysis and obtaining a Target Hazard Quotient (THQ) value ≥ 1, then follow-up actions must be taken. In risk management, a risk management strategy is carried out which includes determining safe limits. Then risk communication is carried out to convey risk information to the community at risk, the government, and interested parties.

5.1.1. Risk management

Ingestion Rate (IR) is the amount of water consumed by an individual from a particular source in a certain period. Ingestion rate is the amount of groundwater consumed by respondents within 24 hours or every day. The intake rate value is used to calculate the level of risk of heavy metals contained in the groundwater consumed. In this context, IR is related to the amount of copper (Cu) and arsenic (As) dissolved in wastewater. The ingestion and dermal rates of respondents for children are 1 L/Day and adults are 2 L/Day. Higher ingestion rates are generally found in adults, while lower ingestion rates likely reflect children or individuals with lower activity. Ingestion is one of the important parameters in environmental health risk studies, especially related to exposure to pollution through ingestion.

The longer a person is exposed to hazardous materials, the greater the intake value and the greater the potential health risks they will receive. The effects of consuming drinking water that has high levels of iron and manganese are closely related to the level and duration of exposure. Generally, the higher the levels of iron and manganese and the longer the exposure, the greater the toxic effects. The higher the intake of exposure, the higher the risk of health problems caused (23).

5.1.2. Exposure duration (ED)

Exposure Duration (ED) is the period during which an individual is exposed to a chemical. The duration of exposure (years) used in this study is real-time and lifetime (non-carcinogenic exposure duration 5-30 years). The duration of exposure of respondents ranged from 12-67 years with an average of 38 years. This shows that most respondents have lived in the study location for a long time, so exposure to pollutants may have occurred in the long term. Long duration of exposure can increase health risks associated with exposure to environmental contaminants. Duration of exposure affects the intake value where the longer the consumption of drinking water (duration of exposure) the greater the intake value and the greater the risk of getting adverse health effects (24).

The high frequency of respondents is because all respondents live in the study location and use groundwater or well water as a source of drinking water consumed daily which can increase the risk of health problems for respondents because respondents are continuously exposed to drinking water containing copper and arsenic. As concluded by previous researchers (25) the magnitude of the risk obtained by respondents is determined by of the frequency of exposure received, where the greater the frequency of someone being exposed to hazardous substances in one year, the greater the health risk that will be received. The longer the duration of the frequency of exposure, the greater the risk of health disorders due to exposure to the agent.

5.1.3. Exposure frequency (EF)

Exposure frequency is the number of days of exposure to respondents at the research location. This high frequency of exposure indicates that respondents experience continuous exposure to environmental pollutants, which can have a significant impact on their long-term health. Exposure frequency is the number of days respondents are exposed at the research location. The frequency of exposure for each person is determined by the length of the year (365 days). The frequency of exposure affects the absorption of iron and manganese into the body and the level of a person's exposure to hazardous substances. The main route of entry of copper and arsenic in groundwater into the human body is through drinking water consumption or through the ingestion route so that the calculation of intake of copper and arsenic exposure is influenced by the concentration of copper and arsenic in wastewater, consumption rate (intake), frequency of exposure, duration of exposure and body weight. For the exposure frequency variable, the default value is 350 days/year (the default value in residential areas for drinking water exposure pathways based on US-EPA 1997), while the consumption rate, exposure duration, and body weight variables are based on information obtained during interviews with 100 respondents (26).

According to the survey conducted, the frequency of exposure to iron and manganese at the research location was 350 days per year (stand exposure). Risks related to exposure to copper and arsenic. The fact that the frequency of exposure of all respondents was 350 days means that all respondents are very likely to have relatively high intake values. The more often and longer a person is polluted or in a polluted environment, the more hazardous substances enter the body and the greater the risk of health problems (27).

5.1.4. Average daily dose (ADD)

The ADD value of each individual is obtained using the formula of concentration multiplication (C), Intake rate (R), exposure frequency (fE), exposure duration (Dt), divided by body weight (Wb) and average period (tvag). The results of the intake calculation show that the intake value increases along with the increasing concentration of Iron and Manganese in the water in the area.

5.1.5. Target hazard quotient (THQ)

Target Hazard Quotient (THQ) is a tool used to evaluate non-carcinogenic risks associated with exposure to chemicals such as copper and arsenic in well water. THQ is calculated by entering the concentration of the contaminant, the level of consumption, frequency, time, and a safe reference dose. The THQ value indicates whether the exposure can hurt health, helps in decision-making about risk control, and helps the public know about the risks. Based on the results of the study, the real-time THQ of copper and arsenic in adults is higher than in children.

5.1.6. Risk management

Risk management not only serves to identify and measure risks but also to formulate effective mitigation strategies. As stated by Bakar et al., risk management must be carried out sustainably and responsive to environmental changes, both internal and external (28). This is especially relevant in the management of wastewater containing heavy metals, where changes in waste composition can affect the management strategies applied.

Heavy metal pollution, including copper, can occur through various pathways, such as industrial waste, agriculture, and domestic activities, all of which contribute to the decline in the quality of clean water available to the community (29). Heavy metals such as copper (Cu) and arsenic (As) often accumulate in aquatic environments due to industrial activities, such as those that occur in ports and industrial areas (11,30). Research shows that the concentration of heavy metals in water often exceeds the established threshold, which can potentially harm human health (31,32).

6. CONCLUSIONS

Based on the research that has been conducted, it was concluded that the highest concentration of copper (Cu) heavy metal was 0.029 ml/L and the lowest was 0.0088 ml/L. The concentration of arsenic (As) heavy metal at points 1, 2, and 3 showed a concentration value of 0.0081 ml/L. Respondents' body weight ranged from 12 kg - 75 kg and an average of 39.6 kg. The ingestion rate of respondents for children was 1 L/Day and adults 2 L/Day. The duration of exposure of respondents ranged from 12 - 67 years with an average of 38 years. The frequency of exposure of respondents ranged from 356 days/year and an average of 356 days/year.

Health risks that can be caused by exposure to copper (Cu) and arsenic (As) heavy metals at PT. Citra Palu Mineral is that exposure to high amounts of copper can cause nausea, vomiting, diarrhea, stomach ache, and even liver or kidney damage. Acute poisoning usually occurs due to the consumption of water or food contaminated with copper. Arsenic exposure can damage the nervous system, causing symptoms such as numbness or tingling in the hands and feet, confusion, and impaired coordination. In severe exposure, arsenic can cause permanent brain damage.

Risk management that can be carried out is reducing the concentration of risk agents if the pattern and time of consumption cannot be changed, reducing the pattern (intake rate) if the concentration of risk agents and time of consumption cannot be changed, reducing the contact time if the concentration of risk agents and consumption patterns cannot be changed.

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